

# Comparing concentric isokinetic thigh muscle strength in female Gaelic football players with and without previous hamstring injury

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## ABSTRACT

Hamstring injury is one of the most common injuries affecting Gaelic footballers, however conflict exists in the literature regarding the presence of strength deficits after hamstring injury. The aim of this study was to determine whether significant thigh muscle weakness is present in female Gaelic footballers after previous hamstring injury. Twenty members of a university senior female Gaelic football team participated in the study. Knee flexion and extension strength were assessed using an isokinetic dynamometer (Biödex) at 60, 180 and 300 degrees per second. Seven players reported a history of hamstring strain, with all injuries occurring on the dominant side. The previously injured hamstrings were significantly stronger on multiple isokinetic comparisons, although these differences only reached statistical significance ( $p < 0.05$ ) at 180 degrees per second. Dominant legs were significantly stronger ( $p < 0.05$ ) than non-dominant legs across numerous strength variables and speeds. Interestingly, thigh muscle weakness was not observed in female Gaelic football players with a history of hamstring injury. In contrast, the hamstrings of the previously injured legs were stronger than the uninjured legs. The significant strength differences found between dominant and non-dominant legs could, however, have been a confounding variable. Rehabilitation must consider aspects other than increasing muscle strength to reduce the risk of recurrence.

**Keywords:** hamstring injury, isokinetics, muscle strength, female

## INTRODUCTION

Gaelic football is the most popular field sport in Ireland<sup>1</sup>. Similar to other sports played at high speed and intensity, a significant rate of injury has been observed in Gaelic football<sup>2,3</sup>. Hamstring injury has been shown to account for up to 12% of all injuries among female inter-county Gaelic footballers<sup>4</sup>. A similarly high rate of hamstring injury has also been found among athletes in other sports, accounting for 14% of all injuries among elite female soccer players<sup>5</sup> and 15% of all injuries among male professional Australian footballers<sup>6</sup>. Of particular frustration for the athletes concerned is the missed playing time, with hamstring injury alone resulting in approximately 21 missed player games per club per year in Australian football<sup>6</sup>. There

have been several factors hypothesised to contribute to the risk of hamstring injury such as inadequate warm-up, fatigue, previous injury, knee muscle weakness or strength imbalance, poor movement discrimination, poor flexibility, increased lumbar lordosis and poor running technique<sup>7</sup>. While there is emerging evidence that the cause of hamstring injury is probably multifactorial<sup>8,9</sup>, much of the existing research has focused on assessment of muscle strength<sup>10,12</sup>. As well as looking at risk factors prospectively<sup>11</sup>, there have been many retrospective trials trying to identify potential deficits present in athletes after hamstring injury<sup>13,14</sup>. Given the personal and financial costs associated with hamstring injuries<sup>10</sup>, the identification of these deficits, if present, is required for the development of suitable rehabilitation programmes, with the twin aims of early return to sport and prevention of recurrence.



Both retrospective and prospective studies have been carried out among male athletes to investigate the relationship between hamstring injury and muscle weakness, with results having been contradictory and inconsistent<sup>10,13,15,16</sup>. Many retrospective studies, across a variety of sports, have found that athletes with a history of hamstring injury had significantly reduced thigh muscle strength and significant strength imbalance when compared to athletes with no history of hamstring injury<sup>13,15,16</sup>. However, other retrospective studies found no such relationship between previous hamstring injury and muscle strength<sup>14,17</sup>. In fact, one study<sup>10</sup> found that athletes with a history of hamstring injury had increased, rather than decreased, hamstring strength after injury. In addition, in two prospective studies carried out among Australian football players<sup>11,12</sup>, it was found that those with pre-season muscle weakness and strength imbalance were at a significantly greater risk of sustaining a hamstring strain. These results were, however, directly contradicted by another prospective trial<sup>10</sup>, which found no such association. The reasons for these very large inconsistencies, in both retrospective and prospective research, are largely unclear. Methodological differences and differences in study populations may explain part of this. It is possible that further sources of confusion are that studies do not all make the same comparisons (within-subject or between-subject), and not all account for the potential effect of limb dominance affecting the results<sup>10,13</sup>.

There has been far less research carried out on female athletes regarding the relationship between hamstring injury and muscle strength. Prospective studies among females have examined soccer players<sup>18,19</sup> and university athletes<sup>20</sup>. The results of these have been equally conflicting, with some suggesting that muscle weakness or imbalance does predispose players to injury<sup>19,20</sup>, and others disagreeing<sup>18</sup>. These studies did not, however, focus on hamstring injuries, but instead examined lower limb injuries in general. In addition, the authors know of only one study of these factors in Gaelic footballers (male)<sup>21</sup>. This study also found significantly reduced thigh muscle strength in male Gaelic footballers with a history of previous injury, despite having returned to full function<sup>21</sup>.

The aim of this retrospective study was to determine whether significant thigh muscle weakness was present among female Gaelic football players with a history of hamstring injury. This could help clarify which rehabilitation strategies might be justified in the management of such players. Additional aims were to take into account the potential effect of limb dominance on muscle strength, and to clarify if any deficits present were found mainly within or between subjects.

## METHODOLOGY

### Participants

Twenty members of a university senior female Gaelic football panel were recruited for this study. The University of Limerick Research Ethics Committee approved the study, and all players provided written informed consent. Players were excluded if they were less than 18 years of age, had sustained a hamstring injury in the six weeks immediately prior to testing, or if they reported any current lower extremity injury that may have interfered with testing. History of hamstring injury in the past two years<sup>13</sup>, and how many times those

players had injured their hamstring were noted from the participants own subjective report, which has been shown to be a valid measure of hamstring injury history<sup>22</sup>. Hamstring injury was defined as a sudden pain and discomfort felt at the back of the thigh which lasted for at least seven days and which prevented players from participating in matches and/or training. This definition was used in similar, previous studies<sup>13,14</sup>. Limb dominance was defined as their preferred kicking leg, similar to previous research<sup>12,21</sup>. All previously injured participants had returned to normal activity and participation levels at the time of the study.

### Muscle strength testing

Muscle strength testing was performed using an isokinetic dynamometer (Biodex System 3), which has been shown to be a reliable method of assessing peak concentric knee flexion and extension<sup>23</sup>. Each subject underwent a standardised, identical procedure, consisting of a warm up, isokinetic test and cool down. The warm up and cool down each consisted of ten minutes jogging followed by five minutes of lower limb muscle stretching. During testing, subjects were in the seated position as recommended by the manufacturers and were secured by a seatbelt system consisting of stabilisation straps. The axis of rotation of the dynamometer was aligned with the centre of the lateral femoral condyle and the resistance pad at the end of the lever arm was positioned two centimetres proximal to the lateral malleolus. Each subject's concentric knee flexion (hamstring) and extension (quadriceps) torque was measured at angular velocities of 60, 180 and 300 degrees per second (deg/sec), similar to previous research<sup>11</sup>. Torque was measured through a predetermined range of knee motion within safety limits specific to each subject. For familiarisation purposes, subjects initially performed three sub-maximal knee flexion and extension trials at each velocity. Testing consisted of one set of six maximal reciprocal repetitions of knee flexion and extension at each velocity with a 60 second rest period between each set, in line with previous research<sup>10</sup>. The order of leg testing was randomised using a random number generator, however the quadriceps was tested before the hamstrings. All torques were corrected for the effects of gravity. Consistent verbal encouragement was given to each subject during the test protocol, but they did not receive any visual feedback from the monitor. A release button on the dynamometer allowed the participants to stop testing at any time, to minimise the risk of injury.

### Statistical analysis

The isokinetic parameters analysed were bilateral concentric quadriceps and hamstrings (i) peak torque, (ii) average peak torque (mean of the six maximal repetitions) and (iii) relative peak torque (peak torque per kilogram body weight), at 60, 180 and 300 deg/sec. Hamstring to quadriceps (HQ) and hamstring to opposite hamstring (H:oppH) ratios were also determined at each velocity for each subject. Average peak torque was used for calculation of isokinetic muscle strength ratios as it has been reported as being the most suitable<sup>24</sup>. Normality of the data was initially established (Kolmogorov-Smirnov test  $p > 0.05$ ). All injuries ( $n=7$ ) occurred on the dominant side. Therefore, for statistical analysis, the injured legs were



'matched' to the non-injured players dominant limbs, to ensure an accurate comparison between subjects. Paired t-tests were then used to compare the strength between the dominant and non-dominant legs of (i) all players, (ii) non-injured players and (iii) previously injured players. In addition, independent t-tests were used to compare (i) the injured (dominant) legs of the injured players and the matched dominant legs of the non-injured group, and (ii) the non-injured (non-dominant) legs of the injured players and the non-dominant legs of the non-injured players. These statistical tests have been used in previous similar studies<sup>10,11</sup>. All data analysis was performed using SPSS 13.0 for Windows. A significance level of  $p < 0.05$  was set for all tests.

## RESULTS

### Participants

Twenty players completed the study. Table 1 shows their baseline characteristics. Seven players reported a history of unilateral hamstring strain in the two years prior to testing, with no players reporting recurrence of the injury during that time. All seven hamstring injuries involved the players' dominant limbs.

**Table 1: The baseline characteristics of the study participants (mean  $\pm$  SD)**

	Injured Players (n=7)	Non-injured Players (n=13)
Age (years)	20.71 $\pm$ 3.3	20.31 $\pm$ 2.69
Weight (kg)	60.71 $\pm$ 5.71	63.85 $\pm$ 9.85
Right leg dominant	6	12

### Within-Subject Comparisons:

#### Dominant versus non-dominant legs of all subjects

The dominant quadriceps were significantly stronger than the non-dominant side for peak torque ( $p=0.028$ ), average peak torque ( $p=0.014$ ) and relative peak torque ( $p=0.024$ ) at 60 deg/sec and for peak torque ( $p=0.04$ ) and relative peak torque ( $p=0.042$ ) at 300 deg/sec. The dominant hamstrings were also found to have significantly greater peak torque ( $p=0.037$ ) and relative peak torque ( $p=0.048$ ) at 60 deg/sec and greater average peak torque ( $p=0.048$ ) at 180 deg/sec than the non-dominant legs.

#### Dominant legs versus non-dominant legs of non-injured players

The results of this comparison showed significantly greater dominant quadriceps peak torque ( $p=0.026$ ), average peak torque ( $p=0.025$ ) and relative peak torque ( $p=0.023$ ) at 60 deg/sec. Hamstring peak torque was also found to be significantly stronger on the dominant side ( $p=0.046$ ) at 60 deg/sec.

#### Injured (dominant) versus non-injured (non-dominant) legs of injured players

As all the players' hamstring injuries were reported on the dominant

side, the comparison of injured and non-injured legs among the injured players was also a comparison of their dominant and non-dominant legs. The results of this analysis (Table 2) showed that the injured legs were not weaker for any variable. The injured hamstrings were actually significantly stronger than the non-injured hamstrings for peak torque ( $p=0.018$ ), average peak torque ( $p=0.012$ ) and relative peak torque ( $p=0.022$ ) at 180 deg/sec. No other significant differences were found.

**Table 2: Within-subject comparison of isokinetic strength variables of the injured (dominant) and non-injured (non-dominant) legs of players with a history of hamstring injury (mean  $\pm$  SD).**

Variable	Injured legs (n=7)	Non-injured legs (n=7)	P value
Qpt60(Nm)	135.48 $\pm$ 14.92	133.67 $\pm$ 16.63	0.734
Qapt60(Nm)	125.84 $\pm$ 16.15	120.48 $\pm$ 20.73	0.364
Qrpt60(Nm/kg)	2.24 $\pm$ 0.23	2.20 $\pm$ 0.23	0.697
Hpt60(Nm)	75.71 $\pm$ 13.41	69.57 $\pm$ 10.15	0.314
Hapt60(Nm)	69.87 $\pm$ 13.48	63.01 $\pm$ 11.98	0.218
Hrpt60(Nm/kg)	1.25 $\pm$ 0.24	1.15 $\pm$ 0.20	0.343
Qpt180(Nm)	100.47 $\pm$ 10.09	93.37 $\pm$ 5.55	0.092
Qapt180(Nm)	94.28 $\pm$ 10.16	87.51 $\pm$ 6.31	0.103
Qrpt180(Nm/kg)	1.66 $\pm$ 0.14	1.54 $\pm$ 0.07	0.079
Hpt180(Nm)	61.50 $\pm$ 5.81	53.55 $\pm$ 8.04	0.018*
Hapt180(Nm)	56.9 $\pm$ 4.47	48.27 $\pm$ 6.57	0.012*
Hrpt180(Nm/kg)	1.01 $\pm$ 0.11	0.88 $\pm$ 0.15	0.022*
Qpt300(Nm)	82.61 $\pm$ 8.22	77.70 $\pm$ 9.51	0.098
Qapt300(Nm)	76.61 $\pm$ 8.34	72.54 $\pm$ 9.92	0.189
Qrpt300(Nm/kg)	1.36 $\pm$ 0.10	1.28 $\pm$ 0.10	0.112
Hpt300(Nm)	60.77 $\pm$ 6.05	59.17 $\pm$ 9.09	0.387
Hapt300(Nm)	57.18 $\pm$ 5.33	54.47 $\pm$ 8.06	0.198
Hrpt300(Nm/kg)	1.00 $\pm$ 0.06	0.97 $\pm$ 0.12	0.389
H:Q60	0.55 $\pm$ 0.93	0.52 $\pm$ 0.06	0.494
H:Q180	0.61 $\pm$ 0.09	0.55 $\pm$ 0.07	0.207
H:Q300	0.75 $\pm$ 0.09	0.75 $\pm$ 0.07	1

Nm= Newton metres, Nm/kg= Newton metres per kilogram bodyweight, SD= Standard deviation, Q= quadriceps, H= hamstrings, H:Q= hamstring to quadriceps ratio, pt= peak torque, apt= average peak torque, rpt= relative peak torque. (\* $p < 0.05$ )



#### Between-subject comparisons:

##### Injured players versus non-injured players

As a result of the paired *t*-tests showing significant within-subject differences between the dominant and non-dominant limbs, further between-subject analysis using independent *t*-tests compared the strength of: (i) the dominant legs of the non-injured players and the matched dominant (injured) legs of the injured players, and (ii) the non-dominant legs of the non-injured players and the matched non-dominant (or non-injured) legs of the injured players. The results for both of these independent *t*-tests showed no significant differences between the injured and non-injured players for either muscle at any of these isokinetic variables. H:oppH ratios were then calculated and the mean ratio was found to be significantly greater among the injured players (Mean  $\pm$  SD=1.195  $\pm$  0.172) than the non-injured players (Mean  $\pm$  SD=1.013  $\pm$  0.13) at 180 deg/sec ( $p=0.016$ ).

#### DISCUSSION

This study compared concentric isokinetic thigh muscle strength between previously hamstring injured and non-injured female Gaelic footballers. The results suggest that thigh muscle weakness was not present in the group of female Gaelic football players with a history of hamstring injury. Players who reported a history of hamstring strain were in fact found to have significantly stronger hamstring peak torque, average peak torque and relative peak torque of their injured legs when compared to their non-injured legs at 180 deg/sec. The injured players also had a significantly greater H:oppH ratio at 180 deg/sec when compared to the non-injured players. No other significant differences were found between the two groups for any of the other strength variables. The fact that the injuries all occurred in the dominant limb, which was also significantly stronger, complicates interpretation of the results. The authors propose that the study results could mistakenly be interpreted as demonstrating a major increase in strength in the previously injured hamstrings after injury if limb dominance was not accounted for. Even taking the effect of dominance into consideration however, it appears that the within-subject differences in strength between previously injured and non-injured limbs cannot all be explained by a simple dominance effect. There was no evidence of any significant between-subject differences.

Some similar retrospective studies have also found no significant weakness among athletes with a history of hamstring injury. Previous retrospective research looking at male Australian footballers<sup>10</sup>, carried out as part of a larger prospective trial, obtained remarkably similar results to the current study. Bennell et al. (1998) compared concentric and eccentric strength variables at 60 and 180 deg/sec between players with and without a history of hamstring injury. They found that those players with previous injuries had significantly stronger concentric peak torque and relative peak torque at both speeds, compared to those without a history of hamstring injury. However, Bennell et al. (1998) found the differences from between-subject comparisons and the current study found these differences from within-subject comparisons. Bennell et al.<sup>10</sup> also only found these differences to be statistically significant for the right, and not the left, leg. They did not match the limbs for the effect of dominance, as the current

study did, but justified this on the basis of no significant difference being found between dominant and non-dominant limbs. The pattern of increased hamstring strength after injury seen in the current study has also been reported in a recent study of Irish hurlers<sup>25</sup>. Other retrospective studies have also found no evidence of significant muscle weakness after hamstring injury<sup>12,14,17,26</sup>. The results of the present study are, however, contrary to the findings of some other retrospective studies<sup>13,15</sup>. A possible explanation for these contradictory results is that the athletes recruited for the current study had a relatively mild injury (injured once and back in full competitive action), similar to Worrell et al.<sup>14</sup>. In contrast, the studies in which subjects were weaker after injury<sup>13,15</sup> had more severe, persistent hamstring problems, and may have been more likely to display muscle weakness. Finally, the results contrast with those of a larger sample of male Gaelic footballers of similar age and playing level, where a significant decrease in hamstring muscle strength was observed in previously injured subjects despite having returned to full function<sup>21</sup>.

In the present study those with a history of hamstring injury were found to have a significantly greater H:oppH ratio at 180 deg/sec than the non-injured players. These results are inconsistent with the results of Bennell et al.<sup>10</sup>, who found no significant differences between injured and non-injured players for this H:oppH ratio. In fact, in a prospective trial, it had been proposed that a low, rather than high, H:oppH ratio resulted in an increased risk of future hamstring injury<sup>11</sup>. The current study also found no significant difference in HQ ratios. Within-subject<sup>11</sup> and between-subject<sup>12,19</sup> differences in this ratio have been described as important predictors of hamstring injury in some, but not all<sup>18</sup>, prospective trials. The vast majority of retrospective trials<sup>10,12,14,15,17,26</sup>, however, have agreed with the current study results regarding no change in HQ ratios after hamstring injury. The differences in results across these isokinetic variables are not easily explained, and possibly reflect the multifactorial and heterogeneous nature of hamstring injuries. In addition, methodological differences across trials including the dynamometer used, dynamometer speed, mode and testing position, as well as sex and sport of the study population, make comparisons difficult. The differences in this study were statistically significant only at 180 deg/sec. There appears to have been a trend towards more within-subject differences at the other speeds, which may have been significant in a larger sample. Previous authors have suggested that 180 deg/sec most replicates the speed of running<sup>20</sup>, however other trials have found slower speeds, such as 60 deg/sec, to be more sensitive at identifying knee muscle strength ratio deficits<sup>11,21</sup>. Finally, the previously injured limbs were on average significantly stronger than the non-injured limbs. There was, however, considerable variability in hamstring muscle strength within the injured group, with the injured leg ranging from being 44% stronger to 15% weaker when compared to the 'good' leg. This may be important, as this would imply that even this small, relatively homogenous population do not all appear to present with the same 'deficits' after hamstring injury. This 'inter-individual dispersion' of isokinetic results has been reported previously in similar research<sup>15</sup>, and may explain some of the conflict among studies, particularly when small samples such as in the current study are considered.



### Dominance

This study found that the dominant limbs were significantly stronger than the non-dominant limbs, possibly related to kicking activities. This is in agreement with recent studies showing a dominance effect in male Gaelic footballers<sup>21</sup>, but not male hurlers<sup>25</sup>. Other studies, however, have found no significant hamstring or quadriceps strength differences between dominant and non-dominant limbs among female soccer players<sup>18</sup> and male Australian football players<sup>10</sup> where similar definitions of leg dominance were used. All hamstring injuries reported in this study were of the players' dominant leg. Bennell et al.<sup>10</sup> reported 71% of hamstring injuries among Australian football players occurring on their dominant (kicking) side, while previous research<sup>27</sup> found that 19% of hamstring injuries among male Australian footballers occurred during kicking. However, both Orchard et al.<sup>11</sup> and Cameron et al.<sup>12</sup> found no significant correlation between leg dominance and hamstring injury occurrence among Australian football players. There may be a slight increase in incidence of hamstring injury in the dominant limb, but the small sample of this study limits interpretation of these findings. As all injuries reported in the present study occurred on the dominant side, comparisons between injured and non-injured legs of the injured players were in fact comparisons between the dominant and non-dominant legs of these players. Dominance could therefore have been a confounding variable for the results of these comparisons, and must be considered when interpreting the results. However, the injured (dominant) legs of the injured players were found to be significantly stronger than the non-injured (non-dominant) legs for hamstring peak torque and relative peak torque at 180 deg/sec. These significant results were not found in the analysis of the dominant and non-dominant legs of non-injured players, which suggests that the significant differences found between injured and non-injured legs of injured players were not merely due to dominance. The fact that there was a difference in the H:oppH ratios further indicates that the within-subject difference for the injured players is not simply a dominance effect, and might truly reflect a slight increase in strength in the previously injured hamstrings. The authors suggest, however, that every effort should be made to take dominance into account in all future similar trials.

### Limitations

Retrospective study designs can confound the causes and effects of injury, preventing predictive conclusions being made from the results. Similar to many other retrospective studies<sup>14</sup>, changes in the participants strength profiles could have occurred between the time of the hamstring injury and the testing, for example due to rehabilitation, which could confound the results. Participants were defined as having a history of hamstring injury if they reported a strain occurring in the two years prior to testing, similar to previous studies<sup>12,13</sup>. However, depending on subjective history risks under or over estimation of injury history, and access to medical files or confirmation of injury using MRI or ultrasound imaging may have reduced the risk of misdiagnosis. Retrospective recall however, has been shown to be highly accurate in recalling the number of injuries and the body regions injured<sup>22</sup>, and is the method of injury identification used in

most similar trials<sup>21,26</sup>. The statistical power-of-the-study-was-limited-due-to-the-small-sample-size-recruited, however the sample size is comparable to previous similar studies<sup>17,26</sup>, and the results are in line with studies of a much larger size<sup>10</sup>. The different sizes of the injured and non-injured groups makes comparisons difficult, but this has been seen in previous studies, and data was analysed in a similar manner<sup>11</sup>. It has been suggested that detecting differences after-injury is easier if eccentric, or mixed concentric/eccentric, testing is used<sup>15,28</sup>. However, the reliability of isokinetic eccentric testing has been questioned, as it may be painful and result in submaximal efforts and even injury during testing<sup>29</sup>. The risk of injury during eccentric testing may be even greater in participants with previous injury, and reduced compliance with eccentric strengthening programmes has previously been reported in the literature<sup>30</sup>. With this in mind, the current study used only concentric muscle testing and used a relatively demanding protocol involving 36 maximal contractions in total. Finally, other isokinetic parameters of strength, including angle to peak torque<sup>26</sup>, may be worth considering in future studies.

### Implications

There is no evidence from this trial to suggest that all female Gaelic footballers post-hamstring injury have residual thigh muscle weakness. If anything, there is a possibility that female Gaelic football players post-hamstring injury have increased hamstring strength, compared to their other side. The reason for this is unclear. It may, as has previously been suggested<sup>10</sup>, reflect the beneficial effect of a rehabilitation programme. It could equally reflect a change in motor-control, as deficits in movement discrimination have been implicated in hamstring strain<sup>12</sup>. If this is the case, it is unclear whether these changes are beneficial or pathological. For example, in some athletes the increased strength could reflect a running style that places abnormally high loads on the hamstring muscle group. There is a need to consider multiple aspects of an athlete's presentation after hamstring injury e.g. running technique, flexibility, motor control and not just an isolated factor such as muscle weakness. Numerous rehabilitation approaches have been shown to have some effectiveness in the rehabilitation of hamstring injury, from stretching<sup>31,32</sup> trunk strengthening and agility training<sup>33</sup> to eccentric hamstring strength training<sup>34</sup> and normalisation of isokinetic strength parameters<sup>35</sup>. It is possible that natural recovery after hamstring injury is not the same for every individual, of every sex, in every sport. The wide range of strength values observed, even within the injured group, supports this. Rehabilitation should take this variability into account, and match the rehabilitation programme to the needs of the individual athlete. It appears that within-subject comparisons are more sensitive to changes in player strength profile than between-subject comparisons, similar to the situation commonly observed in clinical practice among physiotherapists.

### CONCLUSION

In this study, knee muscle weakness was not present in female Gaelic football players with a history of hamstring injury. On the contrary, there was some evidence of an increase in hamstring muscle strength post-hamstring injury. The results should be interpreted with caution



however, due to the small sample size and the risk of limb dominance influencing the results. The existing literature is inconsistent regarding the relationship between muscle strength and previous hamstring injury. This may reflect the fact hamstring injury may be influenced by many factors, with measurement of a single factor being unlikely to adequately explain the occurrence. Therefore, future trials are needed to clarify the deficits present after injury and to determine which factors are causative of hamstring injury among male and female athletes of various sports.

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